

[NAME OF DOCUMENT] PATENT APPLICATION

[REFERENCE NO.] IDK1551A

[SUBMISSION DATE] February 9, 2004

[ADDRESSED TO] Commissioner of Japanese Patent Office, Yasuo

5 IMAI

[INTERNATIONAL PATENT CLASSIFICATION]

H05B 33/14

[INVENTOR]

[ADDRESS OR WHEREABOUTS] 1280, Kamiizumi,

10 Sodegaura-shi, Chiba, Japan

[NAME] Masahide MATSUURA

[INVENTOR]

[ADDRESS OR WHEREABOUTS] 1280, Kamiizumi,

Sodegaura-shi, Chiba, Japan

15 [NAME] Tishihiko IWAKUMA

[INVENTOR]

[ADDRESS OR WHEREABOUTS] 1280, Kamiizumi,

Sodegaura-shi, Chiba, Japan

[NAME] Keiko YAMAMICHI

20 [INVENTOR]

[ADDRESS OR WHEREABOUTS] 1280, Kamiizumi,

Sodegaura-shi, Chiba, Japan

[NAME] Chishio HOSOKAWA

[PATENT APPLICANT]

25 [IDENTIFICATION NUMBER] 000183646

[NAME] Idemitsu Kosan Co.,Ltd.

[REPRESENTATIVE]

[IDENTIFICATION NUMBER] 100086759

[PATENT ATTORNEY]

[NAME] Kihei WATANABE

[REPRESENTATION OF FEE]

**5** [DEPOSIT ACCOUNT NUMBER] 013619

[DEPOSIT AMOUNT] 21,000 yen

[LIST OF SUBMITTED MATTERS]

[NAME OF MATTER] Claims 1

[NAME OF MATTER] Specification 1

**10** [NAME OF MATTER] Drawing 1

[NAME OF MATTER] Abstract 1

[GENERAL POWER OF ATTORNEY NUMBER] 0200131

[NAME OF DOCUMENT] Claims

[Claim 1]

An organic electroluminescent device having a multilayer structure comprising at least an emitting layer and an  
5 electron-transporting layer between a cathode and an anode, the triplet energy gap ( $E_g^T$ ) of a host material forming the emitting layer being 2.52 eV or more and 3.7 eV or less, an electron-transporting material forming the  
electron-transporting layer being different from the host  
10 material, and having hole-transporting properties, and the emitting layer comprising a phosphorescent metal complex compound containing a heavy metal.

[Claim 2]

The organic electroluminescent device according to claim  
15 1, wherein the ionization potential ( $I_p$ ) of the electron-transporting material forming the electron-transporting layer is 5.6 eV or more and less than 6.0 eV.

[Claim 3]

20 The organic electroluminescent device according to claim 1 or 2, wherein the electron-transporting material forming the electron-transporting layer is at least an electron-deficient nitrogen-containing five-membered ring derivative or a nitrogen-containing six-membered ring derivative.

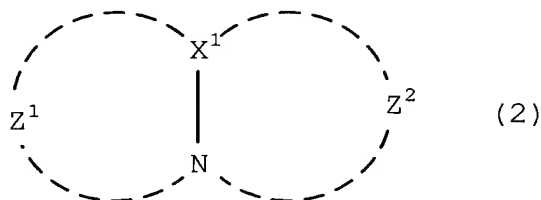
25 [Claim 4]

The organic electroluminescent device according to any one of claims 1 to 3, wherein the electron-transporting material

has one or more of the following structures (1) to (3).  
 Five-membered ring or six-membered ring containing =N- skeleton

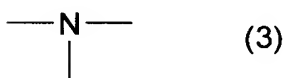
(1)

[FORMULA 1]



wherein X<sup>1</sup> is a carbon atom or a nitrogen atom, and Z<sup>1</sup> and Z<sup>2</sup> are independently atom groups which can form a nitrogen-containing hetero ring

10 [FORMULA 2]



[Claim 5]

The organic electroluminescent device according to any one of claims 1 to 4, wherein the electron-transporting material  
 15 has a nitrogen-containing aromatic polycyclic group containing a five-membered ring or six-membered ring, and when the group contains a plurality of nitrogen atoms, the organic compound has a skeleton containing the nitrogen atoms in non-adjacent bonding positions.

20 [Claim 6]

The organic electroluminescent device according to any one of claims 1 to 5, wherein a difference ( $\Delta I_p = I_p(\text{electron-transporting material}) - I_p(\text{host material})$ ) in

ionization potential between the host material forming the emitting layer and the electron-transporting material forming the electron-transporting layer which contacts the emitting layer is  $-0.2 \text{ eV} < \Delta I_p < 0.4 \text{ eV}$ .

5 [Claim 7]

The organic electroluminescent device according to any one of claims 1 to 6, having a plurality of electron-transporting layers.

[Claim 8]

10 The organic electroluminescent device according to claim 7, wherein a difference ( $\Delta I_p'$ ), represented by the following expression, in ionization potential between electron-transporting materials forming two adjacent layers of the plurality of electron-transporting layers is  $-0.2 \text{ eV} < \Delta I_p'$   
15  $< 0.4 \text{ eV}$ ,

$$\Delta I_p' = I_p(i) - I_p(i+1)$$

wherein  $I_p(i)$  is the ionization potential of an  
20 electron-transporting material forming an  $i$ -th electron-transporting layer from the emitting layer ( $i$  is an integer of 1 or more and  $(N-1)$  or less, and  $N$  is the number of the electron-transporting layers).

[Claim 9]

25 The organic electroluminescent device according to claim 7 or 8, wherein the optical energy gap ( $E_g$ ) of an electron-transporting material forming an

electron-transporting layer is equal to or smaller than the optical energy gap ( $E_g$ ) of an electron-transporting material forming the adjacent electron-transporting layer nearer to the emitting layer.

5 [Claim 10]

The organic electroluminescent device according to any one of claims 7 to 9, wherein the triplet energy gap of an electron-transporting material forming an electron-transporting layer is equal to or smaller than the  
10 triplet energy gap of an electron-transporting material forming the adjacent electron-transporting layer nearer to the emitting layer.

[Claim 11]

The organic electroluminescent device according to any  
15 one of claims 1 to 10, wherein the triplet energy gap of the electron-transporting material forming the electron-transporting layer contacting the emitting layer is larger than the triplet energy gap of the metal complex compound of the emitting layer.

20

[NAME OF DOCUMENT] SPECIFICATION

[TITLE OF THE INVENTION] ORGANIC ELECTROLUMINESCENT DEVICE

[TECHNICAL FIELD]

[0001]

5           The invention relates to an organic electroluminescent device (hereinafter abbreviated as "organic EL device"). More particularly, the invention relates to a highly efficient organic EL device.

[BACKGROUND ART]

10           [0002]

          An organic EL device using an organic substance is a promising solid-state emitting type inexpensive and large full-color display device, and has been extensively developed. An EL device generally includes an emitting layer and a pair  
15 of opposing electrodes holding the emitting layer therebetween.

          In the EL device, electrons and holes are injected into the emitting layer respectively from a cathode and an anode upon application of an electric field between the electrodes. The electrons and the holes recombine in the emitting layer to  
20 produce an excited state, and the energy is emitted as light when the excited state returns to the ground state. The EL device emits light by utilizing this phenomenon.

[0003]

          Various configurations have been known as the  
25 configuration of the organic EL device. For example, use of an aromatic tertiary amine as a material for a hole-transporting layer has been disclosed for an organic EL device having the

device configuration of "indium tin oxide  
(ITO)/hole-transporting layer/emitting layer/cathode" (see  
Patent document 1). This device configuration achieves a high  
luminance of several hundreds  $\text{cd/m}^2$  at an applied voltage of  
5 20 V or less.

[0004]

It has been reported that an emission efficiency of about  
40  $\text{lm/W}$  or more is achieved at a luminance equal to or less than  
several hundreds  $\text{cd/m}^2$  by using an iridium complex  
10 (phosphorescent dopant) as a dopant for an emitting layer (see  
Non-patent document 1).

However, since most phosphorescent organic EL devices  
emit green light, a phosphorescent organic EL device which emits  
blue light has been demanded. Moreover, an increase in the  
15 efficiency of the phosphorescent organic EL device has also been  
demanded.

[0005]

When applying the organic EL device to a flat panel  
display or the like, the organic EL device is required to exhibit  
20 improved emission efficiency and reduced power consumption.  
However, the above-mentioned device configuration has a  
disadvantage in that the emission efficiency significantly  
decreases accompanying an increase in luminance. Therefore,  
it is difficult to reduce the power consumption of the flat panel  
25 display.

[0006]

On the other hand, technologies relating to a hole barrier



layer, which is one of the layers of the organic EL device, have been disclosed (see Patent documents 2 and 3). These technologies improve current efficiency by using an organic compound having a high ionization potential as a material for the hole barrier layer. However, the drive voltage of the organic EL device is disadvantageously increased due to accumulated holes.

[Patent document 1] JP-A-63-295695

[Patent document 2] United States Patent No. 6,097,147

10 [Patent document 3] JP-A-2002-203683

[Non-patent document 1] Tsutsui et al., "Japanese Journal of Physics", Vol. 38 (1999), p. 1502-1504

[DISCLOSURE OF THE INVENTION]

[PROBLEMS TO BE SOLVED BY THE INVENTION]

15 [0007]

The invention was achieved in view of the above-described situation. An object of the invention is to provide a phosphorescent organic EL device which is driven at a low voltage and exhibits high current efficiency.

20 [MEANS FOR SOLVING THE PROBLEMS]

[0008]

According to the invention, the following organic EL device is provided.

1. An organic EL device having a multilayer structure comprising at least an emitting layer and an electron-transporting layer between a cathode and an anode, the triplet energy gap ( $E_g^T$ ) of a host material forming the emitting

25

layer being 2.52 eV or more and 3.7 eV or less, an  
electron-transporting material forming the  
electron-transporting layer being different from the host  
material, and having hole-transporting properties, and the  
5 emitting layer comprising a phosphorescent metal complex  
compound containing a heavy metal.

2. The organic EL device according to 1, wherein the  
ionization potential (Ip) of the electron-transporting  
material forming the electron-transporting layer is 5.6 eV or  
10 more and less than 6.0 eV.

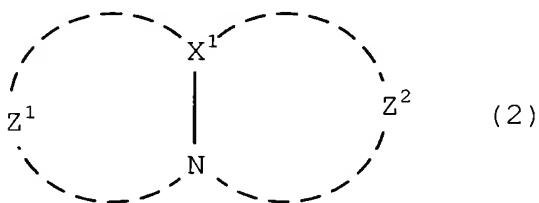
3. The organic EL device according to 1 or 2, wherein the  
electron-transporting material forming the  
electron-transporting layer is at least an electron-deficient  
nitrogen-containing five-membered ring derivative or a  
15 nitrogen-containing six-membered ring derivative.

4. The organic EL device according to any of 1 to 3, wherein  
the electron-transporting material has one or more of the  
following structures (1) to (3).

20 Five-membered ring or six-membered ring containing =N- skeleton

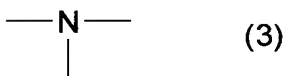
(1)

[FORMULA 3]



wherein  $X^1$  is a carbon atom or a nitrogen atom, and  $Z^1$  and  $Z^2$  are independently atom groups which can form a nitrogen-containing hetero ring

[FORMULA 4]



5. The organic EL device according to any of 1 to 4, wherein the electron-transporting material has a nitrogen-containing aromatic polycyclic group containing a five-membered ring or six-membered ring, and when the group contains a plurality of  
10 nitrogen atoms, the organic compound has a skeleton containing the nitrogen atoms in non-adjacent bonding positions.

6. The organic EL device according to any of 1 to 5, wherein a difference ( $\Delta I_p = I_p(\text{electron-transporting material}) - I_p(\text{host material})$ ) in ionization potential between the host  
15 material forming the emitting layer and the electron-transporting material forming the electron-transporting layer which contacts the emitting layer is  $-0.2 \text{ eV} < \Delta I_p < 0.4 \text{ eV}$ .

7. The organic EL device according to any of 1 to 6, having  
20 a plurality of electron-transporting layers.

8. The organic EL device according to 7, wherein a difference ( $\Delta I_p'$ ), represented by the following expression, in ionization potential between electron-transporting materials forming two adjacent layers of the plurality of  
25 electron-transporting layers is  $-0.2 \text{ eV} < \Delta I_p' < 0.4 \text{ eV}$ ,

$$\Delta I_p' = I_p(i) - I_p(i+1)$$

wherein  $I_p(i)$  is the ionization potential of an electron-transporting material forming an i-th

5 electron-transporting layer from the emitting layer (i is an integer of 1 or more and (N-1) or less, and N is the number of the electron-transporting layers).

9. The organic EL device according to 7 or 8, wherein the optical energy gap ( $E_g$ ) of an electron-transporting material  
10 forming an electron-transporting layer is equal to or smaller than the optical energy gap ( $E_g$ ) of an electron-transporting material forming the adjacent electron-transporting layer nearer to the emitting layer.

10. The organic EL device according to any of 7 to 9,  
15 wherein the triplet energy gap of an electron-transporting material forming an electron-transporting layer is equal to or smaller than the triplet energy gap of an electron-transporting material forming the adjacent electron-transporting layer nearer to the emitting layer.

20 11. The organic EL device according to any of 1 to 10, wherein the triplet energy gap of the electron-transporting material forming the electron-transporting layer contacting the emitting layer is larger than the triplet energy gap of the metal complex compound of the emitting layer.

25 [0009]

In the organic EL device according to the invention, the host material forming the emitting layer is the major material

for the emitting layer, and the phosphorescent metal complex compound containing a heavy metal functions as a luminescent dopant.

5 The electron-transporting layer is positioned on the side of the cathode between the cathode and the anode.

In the invention, the organic EL device according to 1 includes at least one electron-transporting layer. It is preferable that the expression relating to  $\Delta I_p$  be satisfied when the number of electron-transporting layers is one. When the  
10 number of electron-transporting layers is plural, it is preferable that at least the expression relating to  $\Delta I_p$  be satisfied. It is more preferable that at least two adjacent electron-transporting layers satisfy the expression relating to  $\Delta I_p'$ . It is still more preferable that all the adjacent  
15 electron-transporting layers satisfy the expression relating to  $\Delta I_p'$ . This also applies to the case where the number of emitting layers is plural.

[EFFECTS OF THE INVENTION]

[0010]

20 The invention provides, a phosphorescent organic EL device, particularly emitting light in a blue region, which is driven at a low voltage and exhibits high current efficiency.

[BEST MODE FOR CARRYING OUT THE INVENTION]

[0011]

25 An organic EL device according to the invention has a multilayer structure including at least an emitting layer and an electron-transporting layer between a cathode and an anode.

The emitting layer and the electron-transporting layer may respectively have a single-layer configuration or a multilayer configuration.

[0012]

5 In the organic EL device according to the invention, a host material forming the emitting layer has a triplet energy gap ( $E_g^T$ ) of 2.52 eV or more and 3.7 eV or less, preferably 2.75 eV or more and 3.7 eV or less, still more preferably 2.80 eV or more and 3.7 eV or less, particularly preferably 2.9 eV or  
10 more and 3.7 eV or less, and even more preferably 3.3 eV or more and 3.7 eV or less. A host material having a triplet energy gap within the above range allows a luminescent dopant (described later) of an arbitrary color (blue to red) which may be used in the invention to efficiently emit light.

15 [0013]

In the organic EL device according to the invention, an electron-transporting material forming the electron-transporting layer differs from the host material and has hole-transporting properties.

20 This facilitates the hole mobility in the electron-transporting layer, whereby hole accumulation due to the difference in ionization potential between the emitting layer and the electron-transporting layer can be prevented. As a result, an increase in drive voltage can be suppressed.

25 [0014]

The statement "the electron-transporting material has hole-transporting properties" means that hole mobility can be

measured for the electron-transporting material.

The hole mobility may be measured by an arbitrary method. For example, a time of flight method (method which calculates hole mobility from measured charge transit time in an organic film) may be used. In the time of flight method, light having a wavelength absorbed by an organic layer is irradiated to a structure including "electrode/organic layer (layer formed of organic material forming electron-transporting layer)/electrode" to measure the transient current time properties (transit time), and the hole mobility is calculated using the following expression. Note that electron mobility can also be measured by this method.

$$\text{Mobility} = (\text{thickness of organic film})^2 / (\text{field intensity})$$

$$\text{Field intensity} = (\text{voltage applied to device}) / (\text{thickness of organic layer})$$

[0015]

In the invention, it is preferable that the electron-transporting material have a hole mobility ( $\mu(h)$ ) measured by the time of flight method of  $1.0 \times 10^{-7} < \mu(h)$  at a field intensity of  $10^5$  to  $10^7$  V/cm.

[0016]

In the organic EL device according to the invention, the emitting layer includes a phosphorescent metal complex compound (luminescent dopant) containing a heavy metal.

The invention is characterized in that the luminescent

dopant emits light in the organic EL device due to the triplet energy gap.

This allows the hole-electron recombination energy in the organic EL device to be more efficiently transferred to the luminescent dopant to contribute to emission of light.

[0017]

The ionization potential of the electron-transporting material forming the electron-transporting layer is preferably 5.6 eV or more and less than 6.0 eV.

10 [0018]

The difference between the ionization potential of the host material forming the emitting layer and the ionization potential of the electron-transporting material forming the electron-transporting layer which contacts the emitting layer ( $\Delta I_p = I_p(\text{electron-transporting material}) - I_p(\text{host material})$ ) is preferably  $-0.2 \text{ eV} < \Delta I_p < 0.4 \text{ eV}$ , more preferably  $-0.2 \text{ eV} < \Delta I_p < 0.2 \text{ eV}$ .

If the difference  $\Delta I_p$  is in this range, hole accumulation due to the difference in ionization potential between the emitting layer and the electron transporting layer can be prevented. As a result, an increase in drive voltage can be suppressed.

[0019]

When the organic EL device according to the invention includes a plurality of electron transporting layers, the difference ( $\Delta I_p'$ ) in ionization potential between the electron-transporting materials forming two adjacent layers of



the electron-transporting layers represented by the following expression is preferably  $-0.2 \text{ eV} < \Delta I_p' < 0.4 \text{ eV}$ , and still more preferably  $-0.2 \text{ eV} < \Delta I_p' < 0.2 \text{ eV}$ .

5 
$$\Delta I_p' = I_p(i) - I_p(i+1)$$

$I_p(i)$ : ionization potential of electron-transporting material forming  $i$ -th ( $1 \leq i \leq N$ ) electron-transporting layer from the side of the emitting layer

10 If  $\Delta I_p'$  is in this range, since a hole barrier which may cause hole accumulation is reduced, the drive voltage can be reduced, whereby a high luminous efficiency can be obtained.

[0020]

When the organic EL device according to the invention  
15 includes a plurality of electron transporting layers, the optical energy gap ( $E_g$ ) of the electron-transporting material forming each electron-transporting layer is preferably equal to or smaller than the optical energy gap ( $E_g$ ) of the electron-transporting material forming the adjacent  
20 electron-transporting layer nearer to the emitting layer. That is, it is preferable that  $N$  electron transporting layers satisfy the following relationship.

$$E_g(i) \leq E_g(i-1) \leq \cdots \leq E_g(2) \leq E_g(1) \quad (i)$$

25

$E_g(i)$ : optical energy gap of  $i$ -th ( $2 \leq i \leq N$ ) electron transporting layer from the side of the emitting layer

Eg (1): optical energy gap of the electron transporting layer which contacts the emitting layer

[0021]

When the organic EL device according to the invention includes a plurality of electron transporting layers, the triplet energy gap ( $Eg^T$ ) of the electron-transporting material forming each electron-transporting layer is preferably equal to or smaller than the triplet energy gap ( $Eg^T$ ) of the electron-transporting material forming the adjacent electron-transporting layer nearer to the emitting layer. That is, it is preferable that N electron transporting layers satisfy the following relationship.

$$Eg^T (i) \leq Eg^T (i-1) \leq \cdots \leq Eg^T (2) \leq Eg^T (1) \quad (ii)$$

$Eg^T (i)$ : triplet energy gap of i-th ( $2 \leq i \leq N$ ) electron transporting layer from the side of the emitting layer  
 $Eg^T (1)$ : triplet energy gap of the electron transporting layer which contacts with the emitting layer

[0022]

The organic EL device according to the invention preferably satisfies the following expression when the triplet energy gap of the luminescent dopant of the emitting layer is indicated by  $Eg^T$  (dopant).

$$Eg^T (1) > Eg^T (dopant) \quad (iii)$$

The recombination energy in the emitting layer can be prevented from diffusing into the electron transporting layer by satisfying the above expressions (i) to (iii), whereby the energy of the host material is efficiently transferred to the luminescent dopant. As a result, a high current efficiency can be realized.

[0023]

The host material, the luminescent dopant, and the electron transporting material used for the organic EL device according to the invention are not particularly limited insofar as the above-described conditions are satisfied.

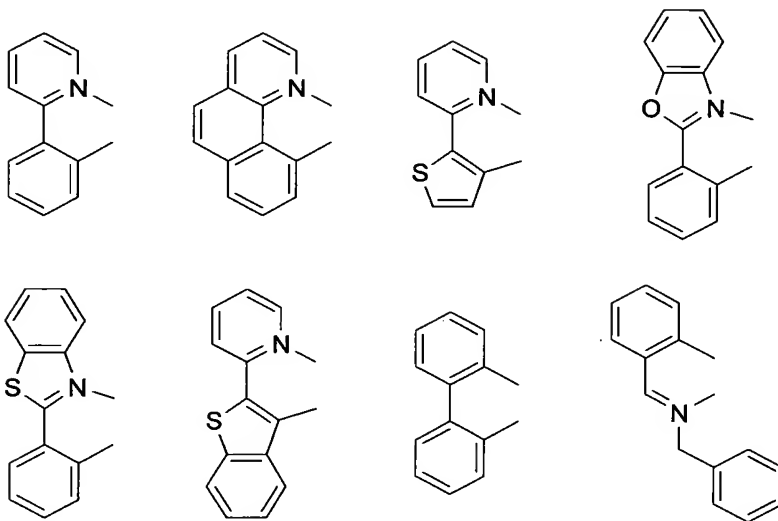
As preferable examples of the host material, compounds exhibiting excellent thin film formability, such as amine derivatives, carbazole derivatives, oxadiazole derivatives, triazole derivatives, benzoxazole type, benzothiazole type, and benzimidazole type fluorescent whitening agents, metal chelate oxanoid compounds, and styryl compounds, can be given. In the invention, an electron transporting material described later may be used as the host material.

[0024]

It is preferable that the luminescent dopant function as a luminescent dopant which emits light from the triplet state at room temperature. As preferable examples of the heavy metal contained in the dopant, Ir, Pt, Pd, Ru, Rh, Mo, and Re can be given. As examples of the ligand to the heavy metal, a ligand which is coordinated or bonded to a metal at C or N (CN ligand) and the like can be given. As specific examples of the ligand,

the following compounds and substituted derivatives thereof can be given.

[FORMULA 5]

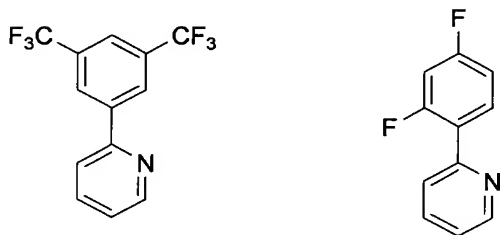


5

As examples of the substituent of the substituted derivatives, an alkyl group, alkoxy group, phenyl group, polyphenyl group, naphthyl group, fluoro (F) group, trifluoromethyl (CF<sub>3</sub>) group, and the like can be given.

10 As preferable examples of a blue light emitting ligand, the following compounds and the like can be given.

[FORMULA 6]



15

[0025]

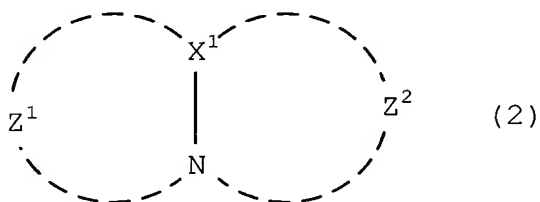
The material used for the electron-transporting layer is

preferably at least an electron-deficient nitrogen-containing five-membered ring derivative or nitrogen-containing six-membered ring derivative. The term "electron-deficient" means that at least one carbon atom of a  $6\pi$  aromatic ring is replaced with a nitrogen atom.

The electron-transporting material is preferably a compound having one or more of the following structures (1) to (3).

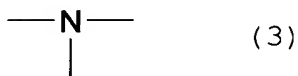
10 Five-membered ring or six-membered ring containing =N- skeleton (1)

[FORMULA 7]



15 In the formula,  $X^1$  is a carbon atom or a nitrogen atom, and  $Z^1$  and  $Z^2$  are independently atom groups which can form a nitrogen-containing hetero ring.

[FORMULA 8]



20

[0026]

The electron-transporting material is still more preferably an organic compound in which one or more of the

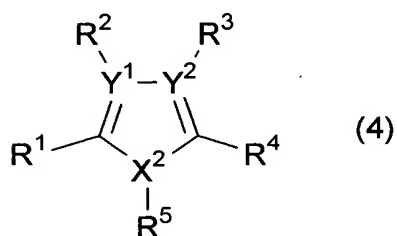
structures (1) to (3) form a nitrogen-containing aromatic polycyclic group containing a five-, six-, seven-, or eight-membered ring, and preferably a five- or six-membered ring, provided that, when the group contains a plurality of  
5 nitrogen atoms, the organic compound has a skeleton containing the nitrogen atoms in non-adjacent bonding positions.

[0027]

As such a compound, a compound having a carbazolyl group, pyridyl group, pyrimidinyl group, pyrazinyl group, triazinyl  
10 group, quinoxalyl group, quinolyl group, imidazolyl group, triazolyl group, tetrazolyl group, oxadiazolyl group, thiadiazolyl group, or oxatriazolyl group (each group may have a substituent) is preferable.

As specific examples of such a compound, compounds having  
15 a structure shown by the following formula (4) can be given.

[FORMULA 9]



In the formula,  $R^1$  to  $R^5$  represent bonding positions,  
20 provided that  $R^1$  and  $R^2$ ,  $R^3$  and  $R^4$ , and  $R^2$  and  $R^3$  may form a ring,  $X^2$  represents nitrogen, and  $Y^1$  and  $Y^2$  individually represent a carbon atom or a nitrogen atom (excluding the case where both of  $Y^1$  and  $Y^2$  represent nitrogen atoms), provided that  $R^2$  or  $R^3$  does not exist when  $Y^1$  or  $Y^2$  represents a nitrogen atom.

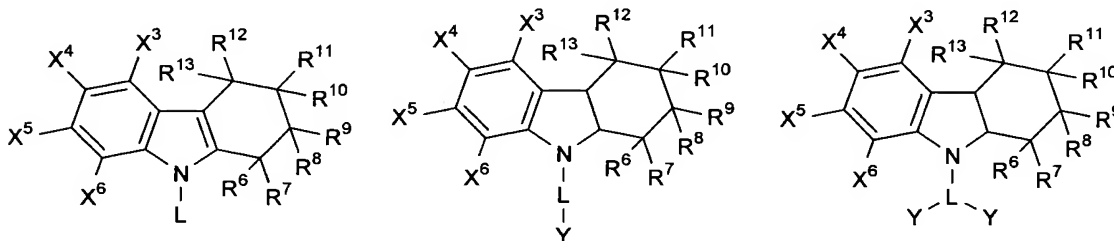
[0028]

It is also preferable that the electron-transporting material be a compound in which at least one of  $R^1$ ,  $R^4$ , and  $R^5$  in the formula (4) is a nitrogen atom or an aromatic ring, and the skeleton shown by the formula (4) is bonded to at least one skeleton shown by the formula (4) through at least one nitrogen atom or aromatic ring; or a compound in which at least one of  $R^1$ ,  $R^4$ , and  $R^5$  in the formula (4) is a nitrogen atom or an aromatic ring and the skeleton shown by the formula (4) is bonded to at least one skeleton shown by the formula (4) through at least one nitrogen atom or aromatic ring, and an alicyclic compound.

[0029]

Specific examples of the compound having the structure shown by the formula (4) are given below.

[FORMULA 10]



In the formulae,  $L$ - represents a bonding position, and bonds to  $N$  directly.  $X^3$  to  $X^6$  are individually represented as  $L'$ ,  $L'-Y$  or  $Y-L'-Y$ , and  $L'$  represents a substituted or unsubstituted aryl group having 6 to 40 carbon atoms, substituted or unsubstituted heterocyclic group having 3 to 40 carbon atoms, substituted or unsubstituted linear or branched alkyl group having 1 to 30 carbon atoms, substituted or

unsubstituted cycloalkyl group having 5 to 40 carbon atoms, substituted or unsubstituted arylene group having 6 to 40 carbon atoms, substituted or unsubstituted di- or higher-valent heterocyclic group having 3 to 40 carbon atoms, substituted or  
5 unsubstituted linear or branched alkylene group having 1 to 30 carbon atoms, or substituted or unsubstituted cycloalkylene group having 5 to 40 carbon atoms. Y represents a substituted or unsubstituted aryl group having 6 to 40 carbon atoms, substituted or unsubstituted heterocyclic group having 3 to 40  
10 carbon atoms, substituted or unsubstituted linear or branched alkyl group having 1 to 30 carbon atoms, or substituted or unsubstituted cycloalkyl group having 5 to 40 carbon atoms.  $R^6$  to  $R^{13}$  individually represent a hydrogen atom, halogen atom, cyano group, silyl group, substituted or unsubstituted amino  
15 group, substituted or unsubstituted aryl group having 6 to 40 carbon atoms, substituted or unsubstituted aryloxy group having 6 to 40 carbon atoms, substituted or unsubstituted heterocyclic group having 3 to 40 carbon atoms, substituted or unsubstituted linear or branched alkyl group having 1 to 30 carbon atoms,  
20 substituted or unsubstituted alkoxy group having 1 to 30 carbon atoms, substituted or unsubstituted aralkyl group having 7 to 40 carbon atoms, or substituted or unsubstituted cycloalkyl group having 5 to 40 carbon atoms.

[0030]

25 Examples of the aryl group of L' include phenyl, 1-naphthyl, 2-naphthyl, 1-anthryl, 2-anthryl, 9-anthryl, 1-phenanthryl, 2-phenanthryl, 3-phenanthryl, 4-phenanthryl,



9-phenanthryl, 1-naphthacenyl, 2-naphthacenyl,  
 9-naphthacenyl, 1-pyrenyl, 2-pyrenyl, 4-pyrenyl, 2-biphenyl, 3-biphenyl, 4-biphenyl, p-terphenyl-4-yl,  
 p-terphenyl-3-yl, p-terphenyl-2-yl, m-terphenyl-4-yl,  
 5 m-terphenyl-3-yl, m-terphenyl-2-yl, o-tolyl, m-tolyl, p-tolyl,  
 p-t-butylphenyl, p-(2-phenylpropyl)phenyl,  
 3-methyl-2-naphthyl, 4-methyl-1-naphthyl, 4-methyl-1-anthryl,  
 4'-methylbiphenyl, 4''-t-butyl-p-terphenyl-4-yl, fluorenyl,  
 perfluoroaryl, 1,1';3',1''-terphenyl-5'-yl,  
 10 1,1';3',1''-terphenyl-2'-yl, and 1,1';3',1''-terphenyl-4'-yl.

[0031]

Examples of the heterocyclic group of L' include pyrrole,  
 pyridine, pyrimidine, pyrazine, triazine, aziridine,  
 azaindolizine, indolizine, imidazol, indole, isoindole,  
 15 indazole, purine, pteridine, and  $\beta$ -carboline.

[0032]

Examples of the alkyl group of L' include methyl,  
 trifluoromethyl, ethyl, propyl, isopropyl, n-butyl, s-butyl,  
 isobutyl, t-butyl, n-pentyl, n-hexyl, n-heptyl, n-octyl,  
 20 hydroxymethyl, 1-hydroxyethyl, 2-hydroxyethyl,  
 2-hydroxyisobutyl, 1,2-dihydroxyethyl,  
 1,3-dihydroxyisopropyl, 2,3-dihydroxy-t-butyl,  
 1,2,3-trihydroxypropyl, chloromethyl, 1-chloroethyl,  
 2-chloroethyl, 2-chloroisobutyl, 1,2-dichloroethyl,  
 25 1,3-dichloroisopropyl, 2,3-dichloro-t-butyl,  
 1,2,3-trichloropropyl, bromomethyl, 1-bromoethyl,  
 2-bromoethyl, 2-bromoisobutyl, 1,2-dibromoethyl,

1,3-dibromoisopropyl, 2,3-dibromo-t-butyl,  
 1,2,3-tribromopropyl, iodomethyl, 1-iodoethyl, 2-iodoethyl,  
 2-iodoisobutyl, 1,2-diiodoethyl, 1,3-diiodoisopropyl,  
 2,3-diiodo-t-butyl, 1,2,3-triiodopropyl, aminomethyl,  
 5 1-aminoethyl, 2-aminoethyl, 2-aminoisobutyl,  
 1,2-diaminoethyl, 1,3-diaminoisopropyl, 2,3-diamino-t-butyl,  
 1,2,3-triaminopropyl, cyanomethyl, 1-cyanoethyl,  
 2-cyanoethyl, 2-cyanoisobutyl, 1,2-dicyanoethyl,  
 1,3-dicyanoisopropyl, 2,3-dicyano-t-butyl,  
 10 1,2,3-tricyanopropyl, nitromethyl, 1-nitroethyl,  
 2-nitroethyl, 2-nitroisobutyl, 1,2-dinitroethyl,  
 1,3-dinitroisopropyl, 2,3-dinitro-t-butyl, and  
 1,2,3-trinitropropyl groups.

[0033]

15 Examples of the cycloalkyl group of L' include  
 cyclopentyl, cyclohexyl, 4-methylcyclohexyl, adamantyl, and  
 norbornyl.

Examples of the arylene group of L' include bivalent  
 groups of the above examples of the aryl group.

20 Examples of the bivalent substituted or unsubstituted  
 heterocyclic group with 3 to 40 carbon atoms of L' include  
 bivalent or more groups of the above examples of the  
 heterocyclic group.

Examples of the alkylene group of L' include bivalent  
 25 groups of the above examples of the substituted or unsubstituted  
 alkyl group.

Examples of the cycloalkylene group of L' include

bivalent groups of the above examples of the substituted or unsubstituted cycloalkyl group.

Examples of the aryl groups, the heterocyclic groups, the alkyl groups and the cycloalkyl groups of Y include the above  
5 examples of L'.

[0034]

Examples of the halogen atom of  $R^6$  to  $R^{13}$  include fluorine, chlorine, bromine, and iodine.

Examples of the aryl group of  $R^6$  to  $R^{13}$  are the same as  
10 the above examples for L'.

The aryloxy groups of  $R^6$  to  $R^{13}$  are represented by -OP.  
Examples of P include phenyl, 1-naphthyl, 2-naphthyl, 1-anthryl, 2-anthryl, 9-anthryl, 1-phenanthryl, 2-phenanthryl, 3-phenanthryl, 4-phenanthryl, 9-phenanthryl, 1-naphthacenyl, 2-naphthacenyl, 9-naphthacenyl, 1-pyrenyl, 2-pyrenyl,  
15 4-pyrenyl, 2-biphenylyl, 3-biphenylyl, 4-biphenylyl, p-terphenyl-4-yl, p-terphenyl-3-yl, p-terphenyl-2-yl, m-terphenyl-4-yl, m-terphenyl-3-yl, m-terphenyl-2-yl, o-tolyl, m-tolyl, p-tolyl, p-t-butylphenyl,  
20 p-(2-phenylpropyl)phenyl, 3-methyl-2-naphthyl, 4-methyl-1-naphthyl, 4-methyl-1-anthryl, 4'-methylbiphenylyl, 4''-t-butyl-p-terphenyl-4-yl, 2-pyrrolyl, 3-pyrrolyl, pyrazinyl, 2-pyridinyl, 3-pyridinyl, 4-pyridinyl, 2-indolyl, 3-indolyl, 4-indolyl, 5-indolyl, 6-indolyl, 7-indolyl,  
25 1-isoindolyl, 3-isoindolyl, 4-isoindolyl, 5-isoindolyl, 6-isoindolyl, 7-isoindolyl, 2-furyl, 3-furyl, 2-benzofuranyl, 3-benzofuranyl, 4-benzofuranyl, 5-benzofuranyl,

6-benzofuranyl, 7-benzofuranyl, 1-isobenzofuranyl,  
 3-isobenzofuranyl, 4-isobenzofuranyl, 5-isobenzofuranyl,  
 6-isobenzofuranyl, 7-isobenzofuranyl, 2-quinolyl, 3-quinolyl,  
 4-quinolyl, 5-quinolyl, 6-quinolyl, 7-quinolyl, 8-quinolyl,  
 5 1-isoquinolyl, 3-isoquinolyl, 4-isoquinolyl, 5-isoquinolyl,  
 6-isoquinolyl, 7-isoquinolyl, 8-isoquinolyl, 2-quinoxaliny, 3-quinoxaliny,  
 5-quinoxaliny, 6-quinoxaliny, 1-carbazolyl, 2-carbazolyl,  
 3-carbazolyl, 4-carbazolyl, 1-phenanthrydiny, 2-phenanthrydiny,  
 3-phenanthrydiny, 4-phenanthrydiny,  
 10 6-phenanthrydiny, 7-phenanthrydiny, 8-phenanthrydiny,  
 9-phenanthrydiny, 10-phenanthrydiny, 1-acrydiny, 2-acrydiny,  
 3-acrydiny, 4-acrydiny, 9-acrydiny,  
 1,7-phenanthroline-2-yl, 1,7-phenanthroline-3-yl,  
 1,7-phenanthroline-4-yl, 1,7-phenanthroline-5-yl,  
 15 1,7-phenanthroline-6-yl, 1,7-phenanthroline-8-yl,  
 1,7-phenanthroline-9-yl, 1,7-phenanthroline-10-yl,  
 1,8-phenanthroline-2-yl, 1,8-phenanthroline-3-yl,  
 1,8-phenanthroline-4-yl, 1,8-phenanthroline-5-yl,  
 1,8-phenanthroline-6-yl, 1,8-phenanthroline-7-yl,  
 20 1,8-phenanthroline-9-yl, 1,8-phenanthroline-10-yl,  
 1,9-phenanthroline-2-yl, 1,9-phenanthroline-3-yl,  
 1,9-phenanthroline-4-yl, 1,9-phenanthroline-5-yl,  
 1,9-phenanthroline-6-yl, 1,9-phenanthroline-7-yl,  
 1,9-phenanthroline-8-yl, 1,9-phenanthroline-10-yl,  
 25 1,10-phenanthroline-2-yl, 1,10-phenanthroline-3-yl,  
 1,10-phenanthroline-4-yl, 1,10-phenanthroline-5-yl,  
 2,9-phenanthroline-1-yl, 2,9-phenanthroline-3-yl,

2,9-phenanthroline-4-yl, 2,9-phenanthroline-5-yl,  
 2,9-phenanthroline-6-yl, 2,9-phenanthroline-7-yl,  
 2,9-phenanthroline-8-yl, 2,9-phenanthroline-10-yl,  
 2,8-phenanthroline-1-yl, 2,8-phenanthroline-3-yl,  
 5 2,8-phenanthroline-4-yl, 2,8-phenanthroline-5-yl,  
 2,8-phenanthroline-6-yl, 2,8-phenanthroline-7-yl,  
 2,8-phenanthroline-9-yl, 2,8-phenanthroline-10-yl,  
 2,7-phenanthroline-1-yl, 2,7-phenanthroline-3-yl,  
 2,7-phenanthroline-4-yl, 2,7-phenanthroline-5-yl,  
 10 2,7-phenanthroline-6-yl, 2,7-phenanthroline-8-yl,  
 2,7-phenanthroline-9-yl, 2,7-phenanthroline-10-yl,  
 1-phenazinyl, 2-phenazinyl, 1-phenothiazinyl,  
 2-phenothiazinyl, 3-phenothiazinyl, 4-phenothiazinyl,  
 1-phenoxazinyl, 2-phenoxazinyl, 3-phenoxazinyl,  
 15 4-phenoxazinyl, 2-oxazolyl, 4-oxazolyl, 5-oxazolyl,  
 2-oxadiazolyl, 5-oxadiazolyl, 3-furazanyl, 2-thienyl,  
 3-thienyl, 2-methylpyrrole-1-yl, 2-methylpyrrole-3-yl,  
 2-methylpyrrole-4-yl, 2-methylpyrrole-5-yl,  
 3-methylpyrrole-1-yl, 3-methylpyrrole-2-yl,  
 20 3-methylpyrrole-4-yl, 3-methylpyrrole-5-yl,  
 2-t-butylpyrrole-4-yl, 3-(2-phenylpropyl)pyrrole-1-yl,  
 2-methyl-1-indolyl, 4-methyl-1-indolyl, 2-methyl-3-indolyl,  
 4-methyl-3-indolyl, 2-t-butyl-1-indolyl, 4-t-butyl-1-indolyl,  
 2-t-butyl-3-indolyl, and 4-t-butyl-3-indolyl groups.

25 [0035]

Examples of the heterocyclic, alkyl and cycloalkyl groups  
 of  $R^6$  to  $R^{13}$  are the same as the above examples for L'.

The alkoxy groups of  $R^6$  to  $R^{13}$  are represented by -OQ. Examples of Q are the same as the above alkyl groups for L'.

[0036]

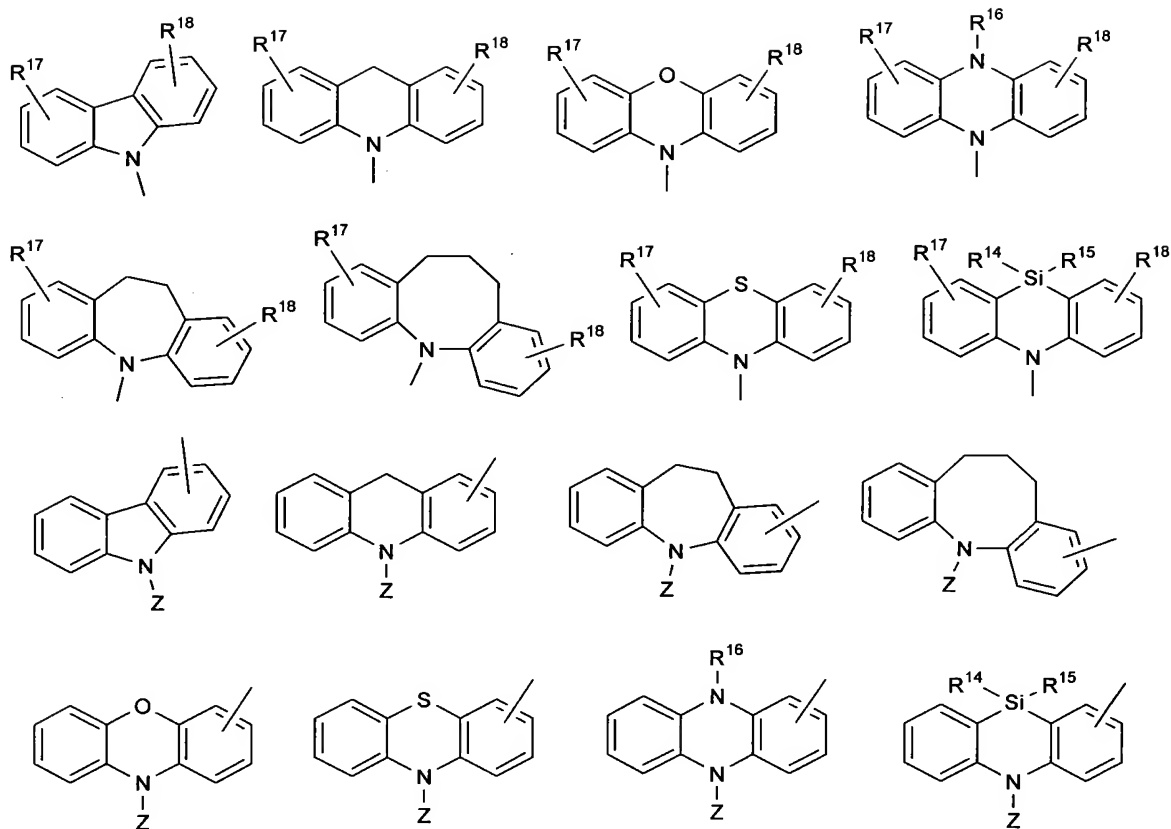
Examples of the aralkyl group of  $R^6$  to  $R^{13}$  include benzyl,  
5 1-phenylethyl, 2-phenylethyl, 1-phenylisopropyl,  
2-phenylisopropyl, phenyl-t-butyl,  $\alpha$ -naphthylmethyl,  
1- $\alpha$ -naphthylethyl, 2- $\alpha$ -naphthylethyl, 1- $\alpha$ -naphthylisopropyl,  
2- $\alpha$ -naphthylisopropyl,  $\beta$ -naphthylmethyl, 1 $\beta$ -naphthylethyl,  
2- $\beta$ -naphthylethyl, 1- $\beta$ -naphthylisopropyl,  
10 2- $\beta$ -naphthylisopropyl, 1-pyrrolylmethyl, 2-(1-pyrrolyl)ethyl,  
p-methylbenzyl, m-methylbenzyl, o-methylbenzyl,  
p-chlorobenzyl, m-chlorobenzyl, o-chlorobenzyl,  
p-bromobenzyl, m-bromobenzyl, o-bromobenzyl, p-iodobenzyl,  
m-iodobenzyl, o-iodobenzyl, p-hydroxybenzyl, m-hydroxybenzyl,  
15 o-hydroxybenzyl, p-aminobenzyl, m-aminobenzyl, o-aminobenzyl,  
p-nitrobenzyl, m-nitrobenzyl, o-nitrobenzyl, p-cyanobenzyl,  
m-cyanobenzyl, o-cyanobenzyl, 1-hydroxy-2-phenylisopropyl,  
1-chloro-2-phenylisopropyl, and trityl groups.

Further detailed examples of the compound shown by the  
20 formula (4) are disclosed in Japanese Patent Application No.  
2002-305375.

[0037]

The electron-transporting material or the host material  
may be a compound having one of the following structures.

25 [FORMULA 11]

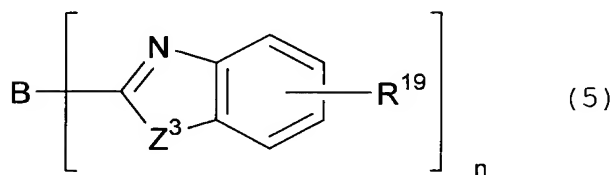


In the formula,  $R^{14}$  to  $R^{18}$  individually represent a hydrogen atom or a substituent having 1 to 40 carbon atoms, provided that  $R^{14}$  and  $R^{15}$  may bond to form a saturated or unsaturated cyclic structure, and Z represents a bonding position.

[0038]

The boron compound shown by the following formula (5) may be mentioned.

10 [FORMULA 12]



wherein n represents an integer from 2 to 8,  $Z^3$  represents O,

NR<sup>20</sup>, or S, R<sup>19</sup> and R<sup>20</sup> individually represent a hydrogen atom, an alkyl group having 1 to 24 carbon atoms such as a propyl group, t-butyl group, or heptyl group, an aryl group or a hetero atom-substituted aryl group such as a phenyl group, naphthyl group, furyl group, thienyl group, pyridyl group, quinolyl group, or another heterocyclic ring group, a halogen group such as a chloro group or fluoro group, or an atom necessary to complete a condensed aromatic ring.

[0039]

10 Benzimidazole derivatives disclosed in Japanese Patent Application No. 2003-067847, metal complexes disclosed in United States Patent No. 5,141,671, and the like may also be used.

[0040]

15 A compound having a carbazolyl group can also be given as a preferable electron-transporting material. An organic compound having a carbazolyl group and a substituted or unsubstituted pyridyl group, pyrazyl group, pyrimidyl group, triazyl group, amino group, or oxadizole group is more  
20 preferable.

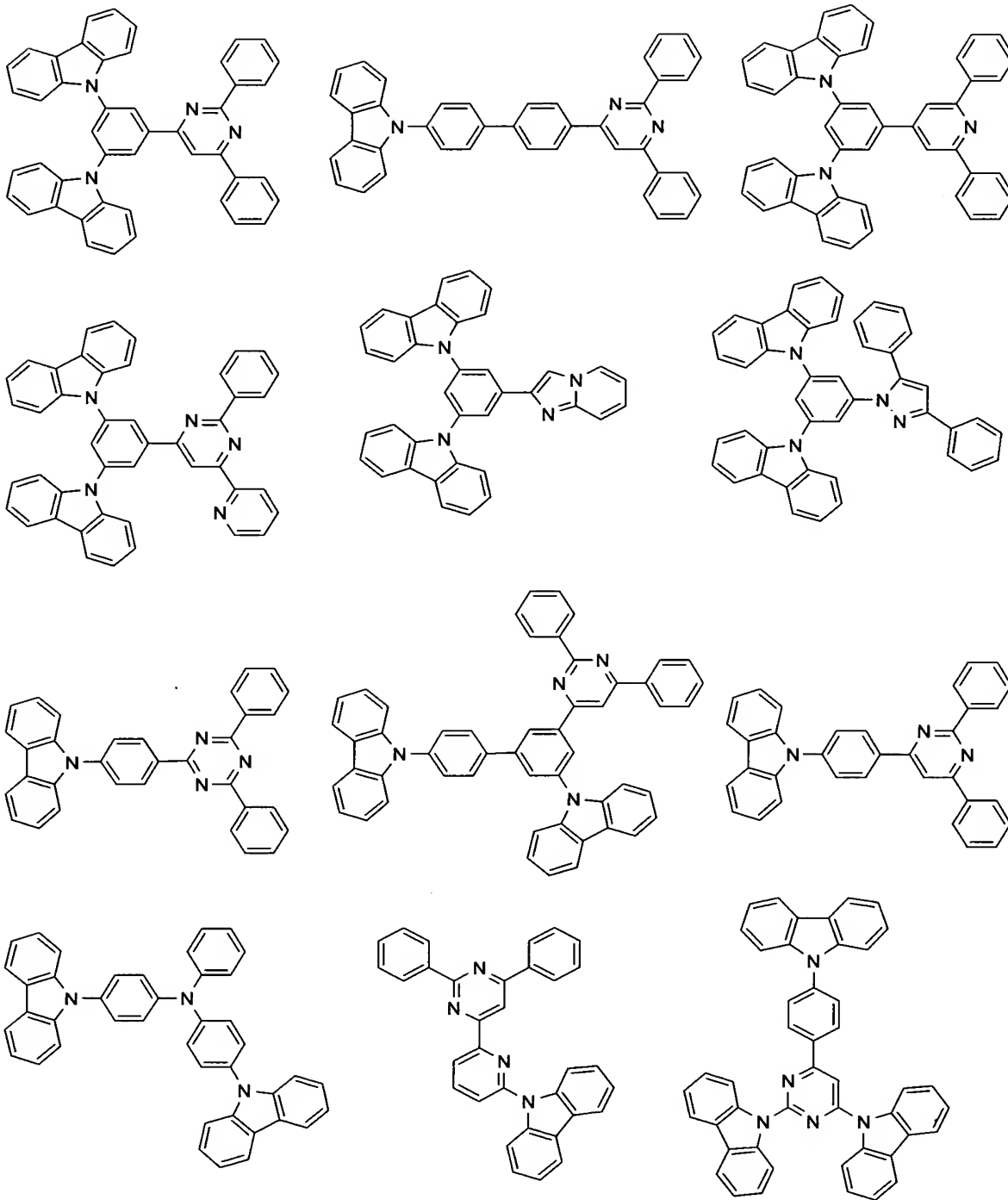
[0041]

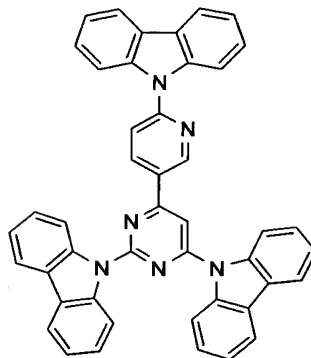
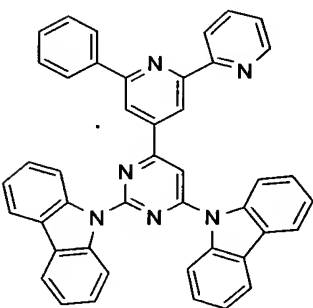
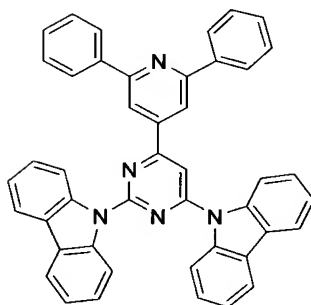
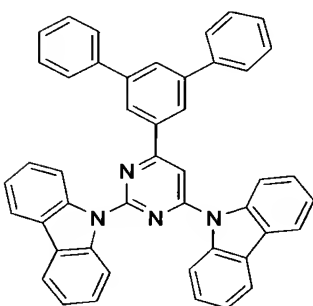
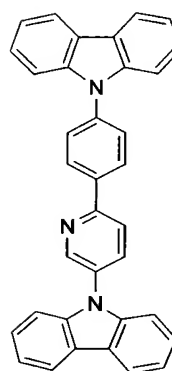
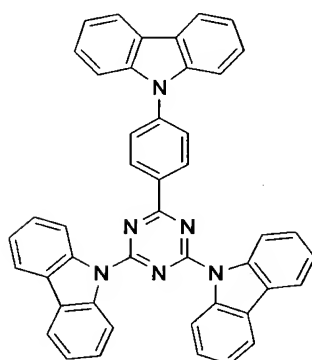
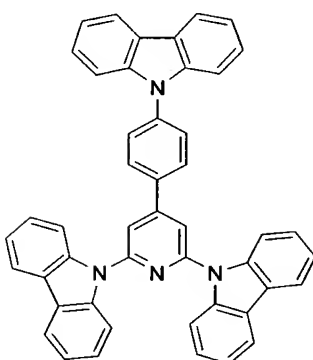
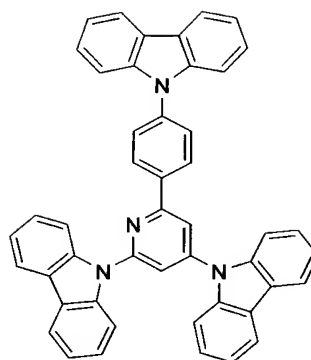
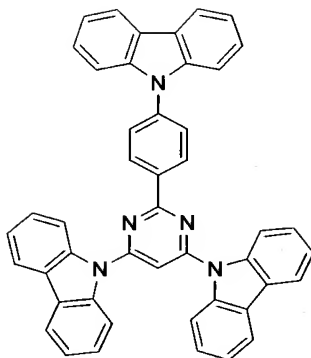
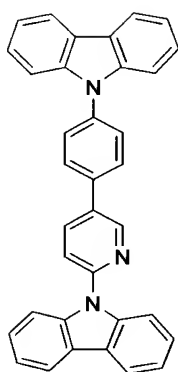
As specific examples of such a compound, compounds disclosed in Japanese Patent Application Nos. 2002-071398, 2002-081234, 2002-071397, 2002-080817, 2002-305375,  
25 2002-360134, and the like can be given.

Examples of the compound having a carbazolyl group are given below.



[FORMULA 13]





In the invention, any of the electron-transporting materials listed above may be used as the host material for the emitting layer.

[0043]

5       As examples of the configuration of the organic EL device according to the invention, the following configurations (a) to (c) can be given.

(a) Anode/emitting layer/electron-transporting layer/cathode

(b) Anode/hole-transporting layer/emitting

10 layer/electron-transporting layer/cathode

(c) Anode/hole-injecting layer/hole-transporting layer/emitting layer/electron-transporting layer/cathode

The emitting layer in the organic EL device according to the invention is a layer obtained by adding a luminescent dopant to the above-described host material. The concentration of the luminescent dopant added to the host material is not particularly limited. The concentration of the luminescent dopant is preferably 0.1 to 20 wt%, and still more preferably 1 to 15 wt% from the viewpoint of current efficiency and drive voltage adjustment.

[0044]

The organic EL device according to the invention is preferably supported by a substrate. The layers may be stacked on the substrate in the order from the anode to the cathode, or may be stacked on the substrate in the order from the cathode to the anode.

It is preferable that at least one of the anode and the

cathode be formed of a transparent or translucent substance in order to efficiently outcouple light from the emitting layer.

[0045]

The material for the substrate used in the invention is not particularly limited. A known material used for an organic EL device such as glass, transparent plastic, or quartz may be used.

[0046]

As the material for the anode used in the invention, a metal, alloy, or electric conductive compound having a work function as large as 4 eV or more, or a mixture of these materials is preferably used. As specific examples of such a material, metals such as Au and dielectric transparent materials such as CuI, ITO, SnO<sub>2</sub>, and ZnO can be given.

The anode may be formed by forming a thin film of the above-mentioned material by deposition, sputtering method, or the like.

When outcoupling light from the emitting layer through the anode, it is preferable that the anode have a transparency of more than 10%.

The sheet resistance of the anode is preferably several hundreds ohm/square or less.

The thickness of the anode is usually 10 nm to 1 micron, and preferably 10 to 200 nm, although the thickness varies depending on the material.

[0047]

As the material for the cathode used in the invention,

a metal, alloy, or electric conductive compound having a work function as small as 4 eV or less, or a mixture of these materials is preferably used. As specific examples of such a material, sodium, lithium, aluminum, magnesium/silver mixture,

5 magnesium/copper mixture, Al/Al<sub>2</sub>O<sub>3</sub>, indium, and the like can be given.

The cathode may be formed by forming a thin film of the above-mentioned material by deposition, sputtering method, or the like.

10 When outcoupling light from the emitting layer through the cathode, it is preferable that the cathode have a transparency of more than 10%.

The sheet resistance of the cathode is preferably several hundreds ohm/square or less.

15 The thickness of the cathode is usually 10 nm to 1 micron, and preferably 50 to 200 nm, although the thickness varies depending on the material.

[0048]

In the organic EL device according to the invention, a  
20 hole-injecting layer, a hole-transporting layer, an electron-injecting layer, and the like may be provided, as required, in order to further increase the current (or luminous) efficiency. The materials for these layers are not particularly limited. A known organic material for an organic  
25 EL may be used. As specific examples of such a material, amine derivatives, stilbene derivatives, silazane derivatives, polysilane, aniline copolymers, and the like can be given.

In the invention, it is preferable to add an inorganic material to the hole-injecting layer, the hole-transporting layer, and the electron-injecting layer. As examples of the inorganic material, metal oxides and the like can be given.

5           An inorganic material may be used between the electron-transporting layer and the cathode in order to increase the current (or luminous) efficiency. As specific examples of the inorganic material, fluorides and oxides of alkali metals such as Li, Mg, and Cs can be given.

10           [0049]

The method of fabricating the organic EL device according to the invention is not particularly limited. The organic EL device according to the invention may be fabricated using a fabrication method used for a known organic EL device. In more  
15 detail, each layer may be formed by vacuum deposition, casting, coating, spin coating, or the like. Each layer may be formed by casting, coating, or spin coating using a solution prepared by dispersing an organic material for each layer in a transparent polymer such as polycarbonate, polyurethane,  
20 polystyrene, polyallylate, or polyester, or each layer may be formed by simultaneous deposition of an organic material and a transparent polymer.

#### EXAMPLES

25           [0050]

The invention is described below in more detail by way of examples. Note that the invention is not limited to the

following examples.

Compounds used in the examples were produced by the methods disclosed in JP-A-10-237438, Japanese Patent Application Nos. 2003-042625, 2002-071398, 2002-081234,  
5 2002-299814, 2002-360134, 2002-071397, 2002-080817, 2002-083866, 2002-087560, and 2002-305375.

[0051]

The parameters shown in the tables were measured by the following methods.

10 (1) Ionization potential ( $I_p$ )

Light (excitation light) from a deuterium lamp dispersed by a monochromator was irradiated to a material, and the resulting photoelectric emission was measured using an electrometer. The ionization potential was determined by  
15 calculating the photoelectric emission threshold value from the photoelectric emission photon energy curve obtained using an extrapolation method. As the measuring instrument, an atmosphere ultraviolet photoelectron spectrometer "AC-1" (manufactured by Riken Keiki Co., Ltd.) was used.

20 (2) Optical energy gap ( $E_g$ )

Light of which the wavelength was resolved was irradiated to a toluene diluted solution of each material, and the optical energy gap was determined by conversion from the maximum wavelength of the absorption spectrum. As the measuring  
25 instrument, a spectrophotometer ("U-3400" manufactured by Hitachi, Ltd.) was used.

(3) Triplet energy gap ( $E_g^T$ )

The triplet energy gap ( $E_g^T$  (Dopant)) was determined by the method described in "HIKARIKAGAKU NO SEKAI", edited by The Chemical Society of Japan, 1993, p. 52. As a measuring equipment, a "F-4500" (Trade name) (manufactured by Hitachi, Ltd.) was used.

In Examples,  $E_g^T$  was obtained by energy conversion from the contact point (shortest wavelength) in the short wavelength component of the spectrum obtained by the measurement.

The hole mobility of the electron transporting material used in Examples could be measured by Time of flight method.

[0052]

Examples 1 to 6

An organic EL device shown in Fig. 1 was fabricated as follows.

A glass substrate 11 (manufactured by Geomatics Co.), measuring 25 mm x 75 mm x 1.1 mm thick, with an ITO transparent electrode (anode) 12 was subjected to ultrasonic cleaning in isopropyl alcohol for 5 minutes and then to UV ozone cleaning for 30 minutes. The cleaned glass substrate 11 with transparent electrode lines was mounted on a substrate holder in a vacuum deposition device. First, a 100 nm thick film of N,N'-bis(N,N'-diphenyl-4-aminophenyl)-N,N-diphenyl-4,4'-diamino-1,1'-biphenyl (hereinafter referred to as TPD 232 film) 13 was formed by resistance heating deposition on the surface where the transparent electrode lines were formed so as to cover the transparent electrode 12. This TPD 232 film 13 functioned as a hole-injecting layer (a hole-transporting layer).



[0053]

After the formation of the TPD 232 film 13, a 10 nm thick hole-transporting layer (hereinafter referred to as HTM) 14 was formed by resistance heating deposition. After the formation  
5 of the hole-transporting layer 14, a host compound (Host No. 1,  $I_p=5.6$  eV,  $E_g=3.53$  eV,  $E_g^T=2.85$  eV) and a luminescent dopant (FIrpic,  $E_g=2.8$  eV,  $E_g^T=2.7$  eV) were co-deposited by resistance heating to form a 30 nm thick film 15 thereon. The concentration of FIrpic was 7.5 wt%. This Host No.1: FIrpic film 15 functioned  
10 as an emitting layer.

[0054]

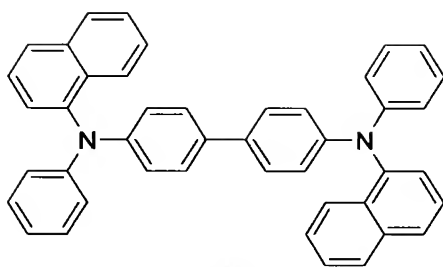
After the formation of the emitting layer 15, a 30 nm thick electron-transporting layer 16 was formed by resistance heating deposition on the emitting layer using electron-transporting  
15 materials shown in Table 1 (ETM\_No.1 (Example 1), ETM\_No.2 (Example 2), ETM\_No.3 (Example 3) PC-7 (Example 4), 8-hydroxyquinolinol aluminum complex (Alq) (Example 5) and BCP (Example 6)).

[0055]

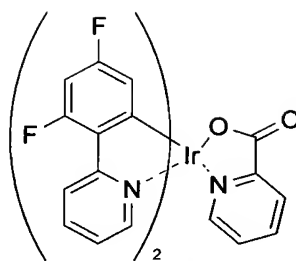
20 Thereafter, a 0.1 nm thick electron-transporting electrode (cathode) 17 was formed of LiF at a film-formation rate of 1 Å/minute. A metal Al was deposited on the LiF layer 17 to form a 130 nm thick metal cathode 18, thereby fabricating an organic EL device 100.

25 [0056]

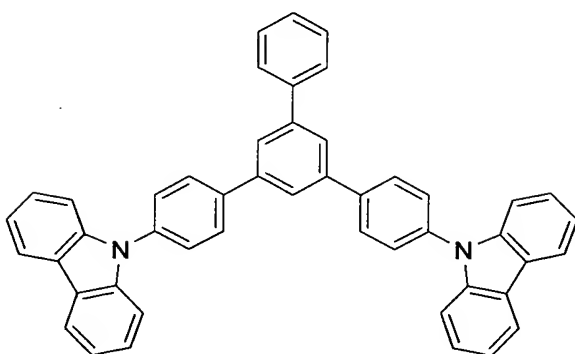
[FORMULA 14]



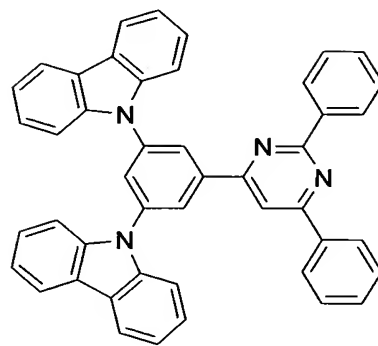
HTM



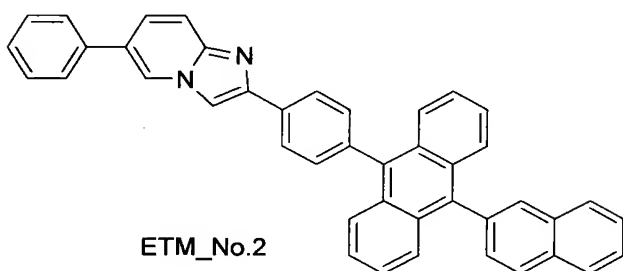
FIrpic



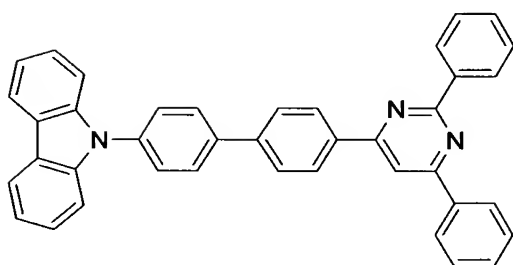
Host No.1



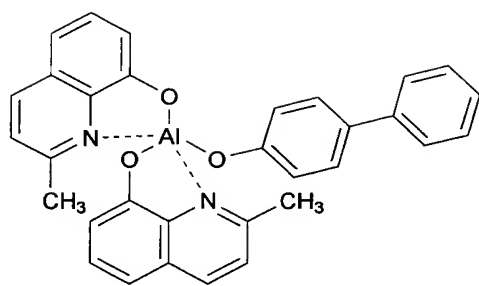
ETM\_No.1



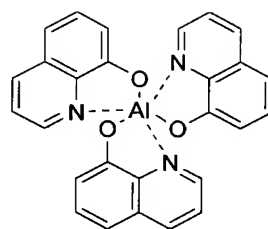
ETM\_No.2



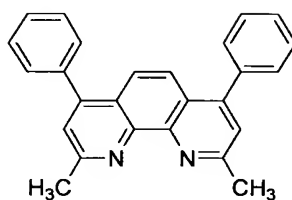
ETM\_No.3



PC-7



Alq



BCP

[0057]

(Evaluation of organic EL device)

5 Luminance, efficiency and chromaticity of the organic EL devices obtained in the examples were measured in the condition of applying a certain DC voltage to calculate a current efficiency  $(=(\text{luminance})/(\text{current density}))$  at a luminance of about  $100 \text{ cd/m}^2$ . The results were shown in Table 1.

Table 1

	Electron-transporting element				Voltage (V)	Current density (mA/cm <sup>2</sup> )	CIE-(x, y)	Current efficiency (cd/A)
	Type	Ip (eV)	Eg (eV)	Eg <sup>T</sup> (eV)				
Example 1	ETM_No.1	5.7	3.5	2.90	6.0	0.83	(0.20, 0.41)	12.0
Example 2	ETM_No.2	5.7	3.0	2.80	7.5	0.58	(0.21, 0.41)	17.0
Example 3	ETM_No.3	5.8	3.3	2.60	6.0	0.83	(0.21, 0.41)	12.0
Example 4	PC-7	5.7	3.0	<3.0	7.5	0.91	(0.21, 0.41)	11.0
Example 5	Alq	5.7	2.7	<2.7	8.0	1.01	(0.21, 0.41)	10.0
Example 6	BCP	6.5	3.9	2.7	9.0	0.99	(0.21, 0.41)	10.1

Emitting layer: Host material (Host No.1); Ip=5.6eV, Eg=3.53eV, Eg<sup>T</sup>=2.85eV

Luminescent dopant (FIrpic); Eg=2.8eV, Eg<sup>T</sup>=2.7eV

These results reveal that the invention realizes a device with a higher current efficiency than conventional devices which have the same emission color.

[0059]

#### 5 Examples 7 and 8

A glass substrate, measuring 25 mm x 75 mm x 1.1 mm thick, with ITO transparent electrode lines (manufactured by Geomatics Co.) was subjected to ultrasonic cleaning in isopropyl alcohol for 5 minutes and then to UV ozone cleaning for 30 minutes. The  
10 cleaned glass substrate with transparent electrode lines was mounted on a substrate holder in a vacuum deposition device. First, a 100 nm thick TPD 232 film was formed by resistance heating deposition on the surface where the transparent  
electrode lines were formed so as to cover the transparent  
15 electrode. The TPD 232 film functioned as a hole-injecting (hole-transporting) layer.

[0060]

After the formation of the TPD 232 film, a 10 nm thick hole-transporting layer (HTM) was formed by resistance heating  
20 deposition. After the formation of the hole-transporting layer, a host material (Host No. 1) and a luminescent dopant (FIrpic) were co-deposited by resistance heating to form a 30 nm thick film thereon. The concentration of FIrpic was 7.5 wt%. This Host No. 1:FIrpic film functioned as an emitting layer.

25 [0061]

After the formation of the emitting layer, a 20 nm thick electron-transporting layer was formed by resistance heating

deposition on the emitting layer using electron-transporting materials; ETM\_No. 1 (Example 7) and ETM\_No. 3 (Example 8).

A 10 nm thick Alq film was further formed to form an electron-transporting layer.

5        Thereafter, a 0.1 nm thick electron-transporting electrode (cathode) was formed of LiF at a film-formation rate of 1 Å/minute. A metal Al was deposited on the LiF layer to form a 130 nm thick metal cathode, thereby fabricating an organic EL device. The device was evaluated. The results are  
10 shown in Table 2.

[0062]

Example 9

An organic EL device of the same structure was fabricated in the same manner as in Example 7 except that ETM\_No. 3 was  
15 used instead of Alq in Example 7. The results are shown in Table 2.

[0063]

Example 10

The same steps as in Example 8 were repeated until the  
20 formation of the ETM\_No. 3 film and then a 10 nm thick Alq film was formed.

Thereafter, a 0.1 nm thick electron-transporting electrode (cathode) was formed of LiF at a film-formation rate of 1 Å/minute. A metal Al was deposited on the LiF layer to  
25 form a 130 nm thick metal cathode, thereby fabricating an organic EL device. The evaluation results are shown in Table 2.

Table 2

	Electron-transporting material				Voltage (V)	Current density (mA/cm <sup>2</sup> )	CIE-(x, y)	Current efficiency (cd/A)
	Type <sup>*)</sup>	Ip (eV)	Eg (eV)	Eg <sup>T</sup> (eV)				
Example 7	Alq	5.7	2.7	< 2.7	6.2	0.29	(0.18, 0.40)	35
	ETM No.1	5.7	3.5	2.90				
Example 8	Alq	5.7	2.7	< 2.7	6.5	0.29	(0.18, 0.40)	36
	ETM No.3	5.8	3.3	2.60				
Example 9	ETM No.3	5.8	3.3	2.60	6.0	0.29	(0.18, 0.40)	37
	ETM No.1	5.7	3.5	2.90				
Example 10	Alq	5.7	2.7	< 2.7	6.0	0.29	(0.18, 0.40)	37
	ETM No.3	5.8	3.3	2.60				
	ETM No.1	5.7	3.5	2.90				

\*) The upper material constitutes the electron-transporting layer on the metal electrode side.

The lower material constitutes the electron-transporting layer contacting the emitting layer.

5 Emitting layer: Host material (Host No.1); Ip=5.6eV, Eg=3.53eV, Eg<sup>T</sup>=2.85eV

Luminescent dopant (FIRpic); Eg=2.8eV, Eg<sup>T</sup>=2.7eV

The results revealed that the invention realizes a device with a higher current efficiency than conventional devices which have the same emission color.

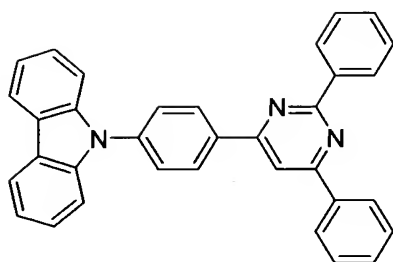
[0065]

**5** Examples 11 to 19

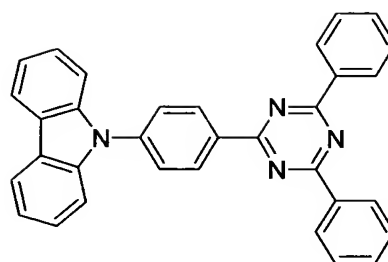
An organic EL device of the same structure was fabricated in the same manner as in Example 7 except that Etm\_No. 4 to ETM\_No. 12 shown below were used instead of ETM\_No. 1 in Example 7. The evaluation results are shown in Table 3.

**10** [0066]

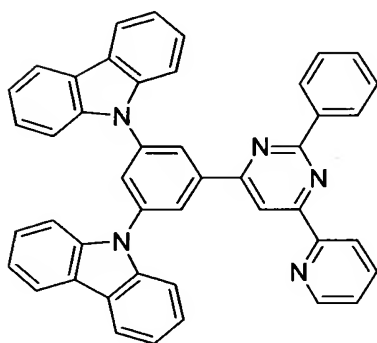




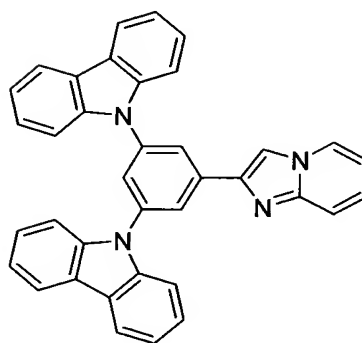
ETM\_No.4



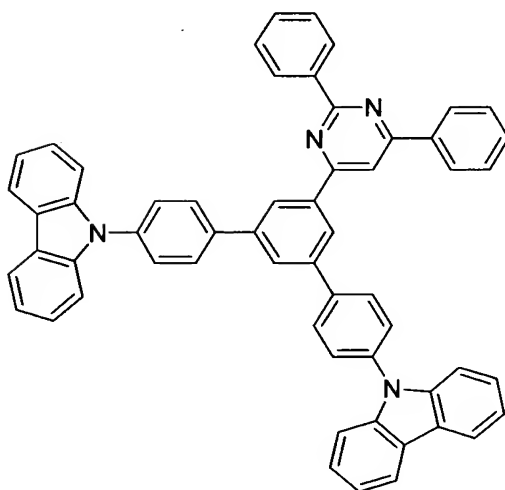
ETM\_No.5



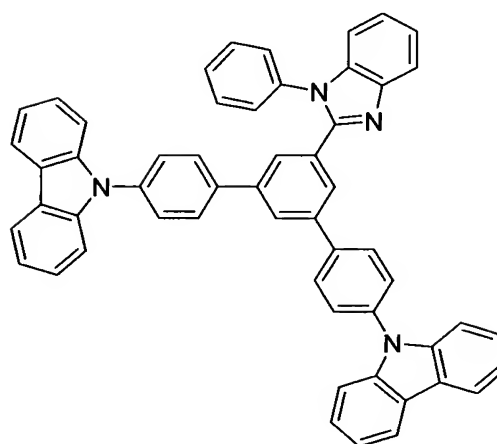
ETM\_No.6



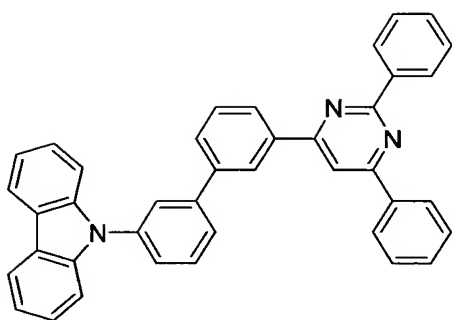
ETM\_No.7



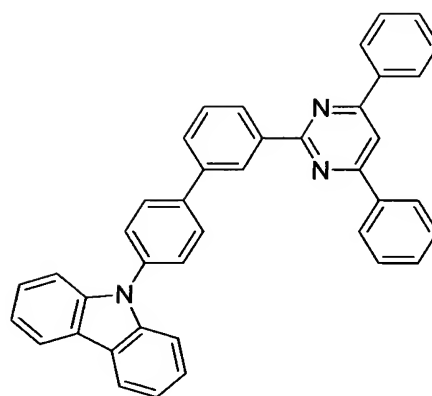
ETM\_No.8



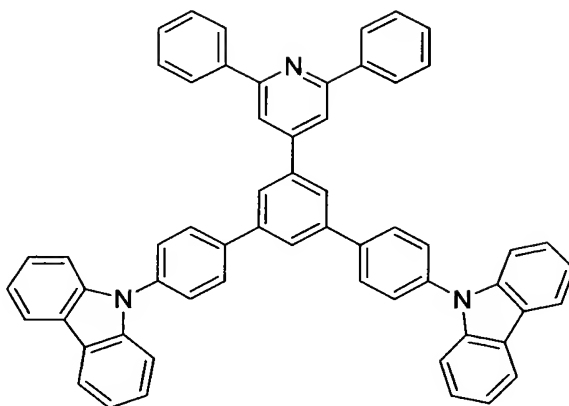
ETM\_No.9



ETM\_No.10



ETM\_No.11



ETM\_No.12

Table 3

Example	Compound	Energy gap		Ip (eV)	Af (=Ip-Eg) (eV)	Voltage (V)	Current density (mA/cm <sup>2</sup> )	Luminance (nit)	chromaticity		Current efficiency (cd/A)
		Eg (eV)	Eg <sup>r</sup> (eV)						x	y	
11	ETM_No.4	3.2	2.8	5.6	2.4	8.28	1.93	462	0.171	0.411	23.9
12	ETM_No.5	3.1	2.8	5.6	2.5	7.47	2.01	447	0.168	0.389	22.3
13	ETM_No.6	3.55	2.9	5.4	1.9	8.18	2.02	486	0.174	0.428	24.1
14	ETM_No.7	3.44	2.8	5.5	2.1	7.89	0.69	115	0.174	0.404	16.7
15	ETM_No.8	3.89	2.9	5.8	1.9	6.68	0.30	100	0.178	0.434	32.9
16	ETM_No.9	3.5	2.8	5.5	2.0	7.96	0.88	101	0.173	0.404	11.5
17	ETM_No.10	3.55	2.9	5.73	2.18	7.71	0.30	102	0.176	0.431	34.1
18	ETM_No.11	3.53	2.88	5.8	2.2	7.35	0.58	101	0.173	0.419	17.4
19	ETM_No.12	3.52	2.83	6.0	2.5	9.20	0.75	99	0.175	0.424	13.2

## Industrial Applicability

[0068]

The organic EL device of the invention can be used for an information display device, a display device for automobiles, lighting and so on because its luminous efficiency is high at a high luminance and the electric power consumption is low. Specifically, it can be suitably used for a flat luminescent body for wall hanging TVs, a back lighting source for displays and so on.

The contents of the documents or publications cited in the description are incorporated herein.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0069]

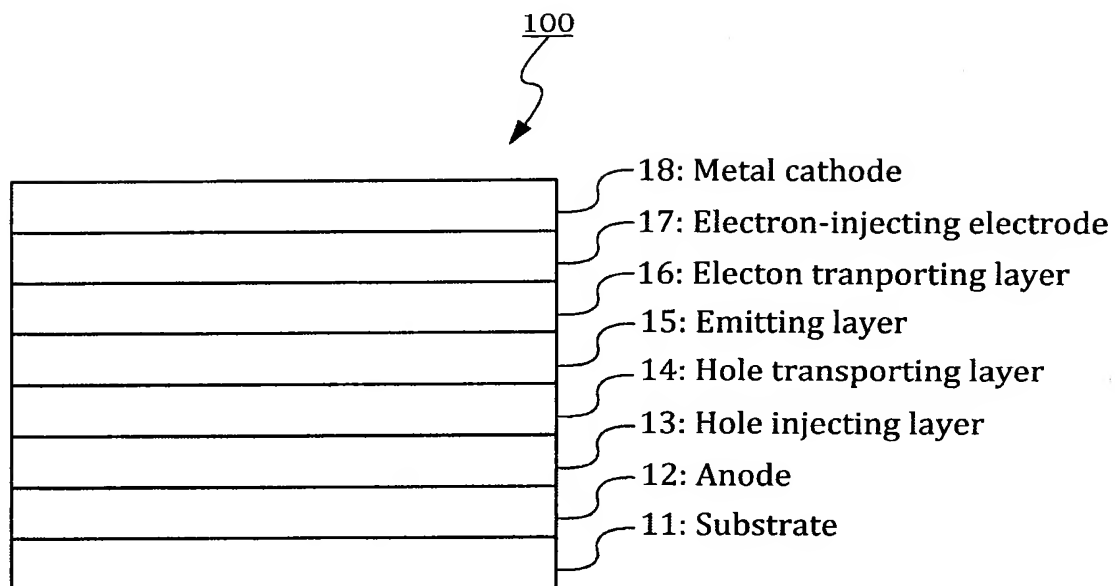
FIG. 1 is a view showing organic EL devices according to Examples 1 to 6.

[DESCRIPTION OF REFERENCE NUMERALS]

[0070]

- 12 Anode
- 15 Emitting layer
- 20 16 Electron transporting layer
- 17 Electron-injecting electrode (Cathode)
- 18 Metal cathode
- 100 Organic EL device

[FIG. 1]



[NAME OF DOCUMENT] ABSTRACT

[ABSTRACT]

[PROBLEMS]

To provide a phosphorescent organic EL device which is  
5 driven at a low voltage and exhibits high current efficiency.

[SOLVING MEANS]

Organic electroluminescent device (100) having a  
multilayer structure including at least emitting layer (15) and  
electron-transporting layer (16) between cathodes (17) and (18)  
10 and anode (12), the triplet energy gap ( $E_g^T$ ) of a host material  
forming emitting layer (15) being 2.52 eV or more and 3.7 eV  
or less, an electron-transporting material forming  
electron-transporting layer (16) being different from the host  
material, and having hole-transporting properties, and  
15 emitting layer (15) including a phosphorescent metal complex  
compound containing a heavy metal.

[SELECTED DRAWING] FIG. 1